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DEVELOPMENT OF A NEW AUTOMATED SYSTEM FOR FORECASTING SURFACE WINDS IN ALASKA

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1. INTRODUCTION

An automated system for forecasting surface winds for the 14 Alaskan stations listed in the first column of Table 1 became operational within the National Weather Service (NWS) in April, 1977 (Carter, 1976; National Weather Service, 1977a). This objective surface wind guidance was based on the Model Output Statistics (MOS) technique (Glahn and Lowry, 1972) and required output from the National Meteorological Center's (NMC's) Primitive Equation (PE) model (Shuman and Hovermale, 1968; National Weather Service, 1977b). On August 13, 1980, the PE model was replaced by the Spectral model (Sela, 1980; National Weather Service, 1980), so after that date the operational surface wind guidance was based on output from the Spectral model.

In general, the conversion to the Spectral model led to a deterioration of the MOS guidance for Alaska. For example, a test performed for probability of precipitation (PoP) forecasts on a sample of 10 cases showed forecasts derived from Spectral model output were on the average 6% worse than forecasts based on PE model output. In addition, comparative verfication tests (Maglaras, 1982) between the old PE-based PoP forecast system and a new system based on output from the Limited-area Fine Mesh (LFM) model (Newell and Deaven, 1981; National Weather Service, 1977c), revealed a slight advantage for the new system.

Assuming that the surface wind guidance in Alaska was adversely impacted by introduction of the Spectral model, and encouraged by the results of the PoP experiment, we decided to develop new, LFM-based equations to forecast surface winds. This new system was expanded to include the stations listed in the second column of Table 1.

2. DEVELOPMENT OF LFM-BASED EQUATIONS

For each season, one set of prediction equations was derived for the 0000 GMT and another for the 1200 GMT cycle runs of the LFM model. Each set includes equations to predict the U and V components, and the wind speed, S, for projections of 12, 18, 24, 30, 36, 42, 48, and 54 hours after the initial model run time. Separate equations were developed for each station. Definitions of the seasons used for this development are: winter (November-March), spring (April-May), summer (June-August), and fall (September-October).

Table 2 shows the potential predictors that were screened. The winter season developmental data consisted of the four seasons of 1977-78, 1978-79, 1979-80, 1980-81, plus part of the 1981-82 season (November-January). Data from 1977 through 1981 comprised the developmental samples for the other three seasons. The potential predictors include several wind related forecast fields from the LFM model, plus the first and second harmonics of the day of the year. For the 12-, 18-, 24-, and 30-h projections, we also screened observations of surface wind, opaque sky cover, and surface temperature available 3 hours after the LFM model input times of 0000 GMT and 1200 GMT. Backup equations, free of observed predictors, are used in day-to-day operations when the necessary observed weather elements are missing. Hence, backup equations also were derived for these four projections.

We allowed the screening procedure to select up to 12 predictors, but only as long as each one reduced the variance of any one of the three predictands (U, V, or S) by an additional three-fourths of one percent. Thus, many of the equations contain less than the full 12 terms.

Nearly all the potential predictors we offered were selected by the screening regression procedure for one station or another. Table 3 lists the 12 most important predictors that comprise the winter season equations for projections of 12, 24, 36, and 48 hours from 0000 GMT. The order of ranking of these predictors was based on a point system, which scored a predictor by the number of times it was chosen and by its position in each equation. Thus, if a predictor was chosen second, it received more points than did a predictor chosen tenth. (For the purpose of this ranking, all predictor projections are combined for each type of variable.) From the table, it is evident that during the winter season observed surface wind components are very important for the 12-h projection. However, for the other three seasons (not shown), the 1000-mb geostropic wind components also are important predictors for the 12-h projection. For projections of 24, 36, and 48 hours, the 1000-mb geostrophic and 850-mb wind components predominated for all four seasons.

Table 4 shows the set of winter season forecast equations for U, V, and S valid 24 hours after 0000 GMT at King Salmon. Here, the 24-h forecasts of 850-mb V and 1000-mb geostrophic S, and the 30-h forecast of 850-mb U were the first three terms selected by the regression procedure. These predictors reduced the variance by 37%, 54%, and 24% for the U, V, and S predictands, respectively. Predictors with valid times before, at, or after the predictand valid time appear in these equations.

3. TESTING

We carried out a comparative verification experiment in order to determine how forecasts from the new, LFM-based equations compare with forecasts from the previously operational, PE-based equations applied to Spectral model output. In particular, we verified forecasts from the original 14 stations listed in column one of Table 1 (these stations also are denoted by closed circles in Fig. 1) for independent data from the period of March 15, 1982 through May 31, 1982, for 18- and 30-h forecast projections. Approximately 90 sample days were available for computing the mean absolute error (MAE) of the wind direction and the wind speed forecasts. In addition, for the wind speed forecasts put into categories, bias values (the number of forecasts divided by the number of observations for specified categories) were calculated.

Table 5 presents the results for all 14 stations. The results indicate that for many locations, especially those in southern Alaska, better forecasts were produced by the older equations. However, in northern Alaska, the new

LFM-based equations made better forecasts. It is evident from the results of speed bias for category II (speeds >12 knots) that the LFM-based equations overestimated the higher wind speeds.

To further study this problem, we decided to compare 18-h LFM-based surface wind forecasts from the 1981 spring season to those from the 1982 spring season for all 39 stations. In order to use the 1981 spring season as an independent sample, we derived new sets of equations withholding this season from the development. In this manner, we attempted to determine if there was some form of LFM model induced degradation in the Alaskan guidance from 1981 to 1982. Table 6 shows the results of this verification in terms of MAE, bias, and percent correct. Note that the results for the 1982 season were slightly worse in terms of the MAE's for speed and direction, and for the percent correct of wind speed. However, there appeared to be no marked decrease in the overall accuracy of the LFM-based system from 1981 to 1982.

4. OPERATIONAL CONSIDERATIONS

Surface wind forecasts from the new, LFM-based surface wind predicton equations are being disseminated as guidance to NWS forecasters in Alaska via the FMAK1 teletype bulletin (National Weather Service, 1983). Wind guidance is provided for the 1-minute average speed and direction valid at specific times 12, 18, 24, 30, 36, 42, 48, and 54 hours after 0000 or 1200 GMT.

In day-to-day operations, we use an "inflation" technique (Klein et al., 1959) to enhance each forecast of speed. This is done because forecasts of wind speed made directly from the regression equations have traditionally shown a tendency to make too few predictions of speeds greater than about 18 knots (Carter, 1975). The inflation technique increases the variance of the speed forecast to equal (or nearly equal) that of the observed wind. As a result, this transformation generates more predictions of strong winds.

Some of the forecast stations are closed during part of each day or report observations erratically. Thus, for certain projections and particular seasons, equations could not be derived for these locations. Tables 7 and 8 summarize the availability of both primary and backup surface wind forecast equations for the 0000 and 1200 GMT cycles, respectively, for all four seasons.

5. SUMMARY

A system for forecasting surface wind for Alaska became operational within the National Weather Service in April 1977. That system was developed with the MOS technique and output from the PE model. On August 13, 1980, the PE model was replaced with the Spectral model, leading to a deterioration of the MOS guidance for Alaska.

Based on the results of several experiments with LFM-based forecasts of temperature, precipitation, cloud amount, and ceiling height conducted on independent data from the winter (November-March) of 1980-81, we decided to redevelop the objective surface wind guidance system for Alaska based on output from the LFM model. Separate sets of equations were derived for both forecast cycles (0000 and 1200 GMT) for four different seasons. These new equations were implemented in September 1982.

A comparative verification of the new LFM-based system and the PE-based system on independent data from the spring of 1981 indicated that the new, LFM-based system did not out-perform the older PE-based system. We think this may be related to performance characteristics of the LFM model in Alaska. Factors such as proximity to the boundary of the LFM grid or the lack of a complete set of observations for the initialization of the LFM model also may have influenced the results.

REFERENCES

Carter, G. M., 1975: Automated prediction of surface wind from numerical model output. Mon. Wea. Rev., 102, 866-873.

_____, 1976: Automated prediction of surface winds in Alaska--No. 1. TDL Office Note 76-15, National Weather Service, NOAA, U.S. Department of Commerce, 6 pp.

Glahn, H. R., and D. A. Lowry, 1972: The use of Model Output Statistics (MOS) in objective weather forecasting. J. Appl. Meteor., 11, 1203-1211.

Klein, W. H., B. M. Lewis, and I. Enger, 1959: Objective prediction of five-day mean temperature during winter. J. Appl. Meteor., 16, 672-682.

Maglaras, G. M., 1982: Development of an improved automated system for forecasting the probability of precipitation in Alaska. TDL Office Note 82-9, National Weather Service, NOAA, U.S. Department of Commerce, 17 pp.

National Weather Service, 1977a: Alaskan maximum/minimum temperature, surface wind, and probability of precipitation FMAK1 bulletin. NWS Technical Procedures Bulletin No. 202, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 5 pp.

_____, 1977b: The 7LPE model. NWS Technical Procedures Bulletin No. 218, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 14 pp.

_____, 1977c: High resolution LFM (LFM-II). NWS Technical Procedures Bulletin No. 206, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 6 pp.

_____, 1980: Spectral modeling at NMC. NWS Technical Procedures Bulletin No. 282, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 14 pp.

_____, 1983: Alaskan temperature, surface winds, probability of precipitation, conditional probability of frozen precipitation, and cloud amount guidance (FMAK1 bulletin). NWS Technical Precedures Bulletin No. 329, National Oceanic and Atmospheric Administration, U. S. Department of Commerce, 16 pp.

Newell, J. E., and D. G. Deaven, 1981: The LFM-II model--1980. NOAA Technical Memorandum NWS NMC-66, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 20 pp.

Sela, J. G., 1980: Spectral modeling at the National Meteorological Center. Mon. Wea. Rev., 108, 1279-1292.

Shuman, F. G., and J. B. Hovermale, 1968: An operational six-layer primative equation model. J. Appl. Meteor., 7, 525-547.

Table 1. Developmental data stations used by the LFM-based and PE-based surface wind guidance systems (also see Fig. 1).

Stations used by both LFM and PE-based systems		Additional stations used in the LFM-based system only	
Anchorage	ANC	Anchorage Elmendorf	PAED
Annette	ANN	Bettles	BTT
Pt. Barrow	BRW	Big Delta	BIG
Barter Island	BTI	Cape Lisburne	PALU
Bethel	BET	Cape Newenham	PAEH
Cold Bay	CDB	Cape Romanzof	PACZ
Fairbanks	FAI	Cordova	CDV
Juneau	JNU	Dillingham	DLG
King Salmon	AKN	Fairbanks Eielson	PAEI
Kotzebue	OTZ	Galena	PAGA
McGrath	MCG	Gulkana	GKN
Nome	OME	Homer	HOM
St. Paul Island	SNP	Indian Mountain	PAIM
Yakutat	YAK	Kenai	ENA
		Kodiak Island	ADQ
		Northway	ORT
		Petersburg	PSG
		Sitka	SIT
		Skagway	SGY
		Sparrevohn	PASV
		Talkeetna	TKA
		Tanana	TAL
		Tatalina	PATL
		Tin City	PATC
		Valdez	VDZ

Table 2. Potential predictors available to the screening regression program for the derivation of new surface wind prediction equations.

Predictors	Projection (hours from model run time)
a) LFM Model Output	
Geostrophic U, V, S (1000 mb)	6, 12, 18, 24, 30, 36, 42, 48
U, V, S (850, 500 mb)	6, 12, 18, 24, 30, 36, 42, 48
U, V, S (700, 200 mb)	12, 24, 36, 48
Constant pressure height (1000 mb, 850 mb, 700 mb, 500 mb)	6, 12, 18, 24, 30, 36, 42, 28
Temperature (1000 mb)	12, 24, 36, 48
Temperature (850 mb, 700 mb)	6, 12, 18, 24, 30, 36, 42, 48
Dew point temperature	6, 12, 18, 24, 30, 36, 42, 48
Mean relative humidity (1000-490 mb)	6, 12, 18, 24, 30, 36, 42, 48
Precipitable water	6, 12, 18, 24, 30, 36, 42, 48
Vertical velocity (850 mb, 700 mb)	12, 24, 36, 48
Sea level pressure	12, 24, 36, 48
b) Model Output Derived Predictors	
Stability (850-mb temp - 1000-mb temp)	12, 24, 36, 48
Stability (700-mb temp - 850-mb temp)	12, 24, 36, 48
Stability (500-mb temp - 700-mb temp)	12, 24, 36, 48
Dew-point depression (850 mb, 700 mb)	6, 12, 18, 24, 30, 36, 42, 48
Dew-point depression (1000 mb)	12, 24, 36, 48
Thickness (500-mb ht - 1000-mb ht)	0, 6, 12, 18, 24, 30, 36, 42, 48
Thickness (850-mb ht - 1000-mb ht)	0, 6, 12, 18, 24, 30, 36, 42, 48
Thickness (700-mb ht - 850-mb ht)	0, 6, 12, 18, 24, 30, 36, 42, 48
Relative vorticity (850 mb, 500 mb)	6, 12, 18, 24, 30, 36, 42, 48
Wind divergence (850 mb, 500 mb)	6, 12, 18, 24, 30, 36, 42, 48
Temperature advection (850 mb)	6, 12, 18, 24, 30, 36, 42, 48
Stability indices (K index, TT index)	6, 12, 18, 24, 30, 36, 42, 48
Sea level pressure difference (12-24 h, 36-48 h)	24, 48
c) Observed and Geoclimatic Predictors	
Sine and Cosine of the day of the year and twice the day of the year	--
Observed weather elements (opaque sky cover, temperature, dew point, U, V, S)	3

Table 3. The 12 most important predictors ranked according to the number of times they were chosen and by their position in the forecast equations for the 0000 GMT cycle winter season development.

Rank	Forecast Projection (in hours from 0000 GMT) 12	24	36	48
1	Observed S	1000-mb geo. S	1000-mb geo. V	1000-mb geo. V
2	Observed V	1000-mb geo. V	1000-mb geo. U	850-mb U
3	1000-mb geo. S	1000-mb geo. U	850-mb S	1000-mb geo. U
4	1000-mb geo. V	850-mb U	850-mb U	1000-mb geo. S
5	Observed U	850-mb V	850-mb V	850-mb V
6	1000-mb geo. U	850-mb S	1000-mb geo. S	850-mb S
7	850-mb U	850-mb rel.vort.	700-mb V	Cosine twice day
8	850-mb S	Observed S	Mean Rel. hum.	Cosine day
9	850-mb V	Mean Rel. hum.	500-mb S	Sine day
10	850-mb rel. vort.	Observed temp.	500-mb V	700-mb S
11	850-mb vert. vel.	Cosine day	700-mb S	850-vert. vel.
12	700-mb S	700-mb S	500-mb ht.	500-mb S

Table 4. Sample equations for estimating the U and V wind components and the wind speed, S, 24 hours after 0000 GMT at King Salmon. The LFM forecast data sample consisted of 610 days from the winter seasons of 1977-78 through 1981-82.

Predictor	Forecast Projection (h)	Cumulative Reduction of Variance			Coefficients			Units
		U	V	S	U	V	S	
Regression Constant	--	---	---	---	0.571	-2.247	6.062	kt
1. 850-mb V	24	0.177	0.437	0.018	0.24	0.370	-0.243	m s^{-1}
2. 1000-mb geostropic S	24	0.205	0.439	0.236	0.057	0.130	0.412	m s^{-1}
3. 850-mb U	30	0.368	0.543	0.237	0.503	0.048	-0.249	m s^{-1}
4. 850-mb relative vorticity	24	0.374	0.544	0.276	-1.379	0.629	0.934	s^{-1}
5. 500-mb S	30	0.397	0.547	0.289	-0.161	0.048	0.105	m s^{-1}
6. Cosine day of year	--	0.398	0.548	0.315	1.167	-1.046	-3.485	none
7. 1000-mb geostrophic U	30	0.398	0.567	0.318	0.005	0.393	0.137	m s^{-1}
8. 1000-mb geostrophic V	24	0.404	0.579	0.318	-0.234	0.264	0.319	m s^{-1}
9. 700-mb V	36	0.416	0.579	0.323	0.269	-0.085	0.223	m s^{-1}
10. 850-mb relative vorticity	18	0.428	0.580	0.325	0.112	0.152	-0.109	s^{-1}
11. 500-mb relative vorticity	30	0.429	0.590	0.327	-0.180	-0.512	-0.207	s^{-1}
12. 1000-mb geostrophic V	30	0.430	0.590	0.330	-0.012	-0.061	-0.274	m s^{-1}
Total standard error of estimate (kt)		5.84	5.44	5.09				

Table 5. Comparative verification results for the new LFM-based surface wind equations and the old, PE-based equations for 14 stations in Alaska for the period March 15, 1982-May 31, 1982 (0000 GMT forecast cycle).

Proj. (h)	Station	Speed Mean Abs. Error (kt) (LFM)	(PE)	No. of Cases	Dir. Mean Abs. Error (deg) (LFM)	(PE)	No. of Cases	Cat. I Bias (spd. ≤12 kt) (LFM)	(PE)	No. of Cases	Cat. II Bias (spd. >12 kt) (LFM)	(PE)	No. of Cases	Percent Correct (%) (LFM)	(PE)
	Annette	4.31	4.14	74	39.6	40.1	71	0.93	1.05	58	1.05	0.81	16	55.4	52.7
	Juneau	3.84	4.00	74	39.1	35.7	57	0.85	1.05	62	1.58	0.75	12	41.9	62.2
	Yakutat	3.39	3.24	72	51.1	45.5	61	0.93	1.00	69	2.67	1.00	3	61.1	68.1
	King Salmon	3.88	3.76	74	39.2	42.4	73	1.00	1.17	53	1.00	0.57	21	41.9	51.4
	Cold Bay	6.42	5.22	74	30.3	27.8	67	1.33	1.13	24	0.84	0.94	50	28.4	29.7
	St. Paul Isl.	4.95	4.21	73	31.8	28.2	71	0.88	1.33	27	1.13	0.80	46	35.6	39.7
	Fairbanks	4.45	3.26	74	69.0	80.0	51	0.90	1.01	73	8.00	0.00	1	60.8	78.4
18-h	Anchorage	3.15	3.66	74	76.7	57.5	69	1.03	1.03	65	0.78	0.78	9	56.8	55.4
	McGrath	3.22	3.03	73	39.2	38.8	51	0.98	1.01	65	1.13	0.88	8	68.5	67.1
	Bethel	4.42	3.27	74	36.4	33.6	73	0.89	1.08	48	1.19	0.84	26	39.2	54.1
	Kotzebue	4.81	6.86	73	39.0	50.1	70	1.04	0.94	45	0.93	0.75	28	39.7	31.5
	Nome	3.47	4.51	73	43.3	34.2	61	0.95	1.09	64	1.33	1.56	9	60.3	58.9
	Barter Isl.	5.39	6.35	74	58.6	54.3	66	0.82	0.71	55	1.53	1.84	19	33.8	24.3
	Pt. Barrow	2.85	2.69	74	30.7	32.5	74	0.95	1.00	61	1.23	1.00	13	54.1	51.4
	Overall Avg.	4.18	4.16	1030	44.0	42.4	915	0.95	1.03	769	1.14	0.92	261	48.3	51.7
	Annette														
	Juneau	4.06	3.93	68	20.5	17.4	41	0.90	0.98	59	1.67	1.11	9	63.2	66.2
	Yakutat	3.21	3.56	71	39.8	53.0	52	1.05	1.08	62	0.67	0.44	9	71.8	69.0
	King Salmon	4.06	3.90	71	36.9	42.2	70	0.90	1.00	54	1.29	1.00	17	40.8	42.3
	Cold Bay	7.62	5.87	71	33.3	29.4	64	1.85	1.30	20	0.67	0.88	51	29.6	28.2
	St. Paul Isl.	5.44	4.21	61	33.7	31.7	60	0.74	1.13	23	1.16	0.92	38	34.4	39.3
	Fairbanks	3.18	2.99	71	56.3	59.4	63	1.00	1.06	65	1.00	0.33	6	47.9	47.9
30-h	Anchorage	5.32	4.58	71	60.6	57.8	48	1.17	1.14	58	0.23	0.38	13	42.3	36.6
	McGrath	3.35	2.77	71	53.7	51.6	59	0.99	0.94	69	1.50	3.00	2	66.2	64.8
	Bethel	4.89	3.80	71	39.1	45.7	69	1.02	1.10	41	0.97	0.87	30	29.6	46.5
	Kotzebue	6.44	8.29	70	45.2	43.2	65	0.80	0.80	51	1.53	1.53	19	21.4	27.1
	Nome	3.72	4.30	71	55.4	46.4	65	0.83	0.79	66	3.60	3.80	5	49.3	47.4
	Barter Isl.	5.85	4.83	71	64.3	58.8	65	0.84	0.82	51	1.25	1.45	20	26.8	22.5
	Pt. Barrow	3.23	3.39	70	30.3	44.0	69	0.90	0.94	58	1.50	1.25	12	50.0	50.0
	Overall Avg.	4.64	4.34	908	44.0	45.4	790	0.97	0.97	677	1.08	1.08	231	44.2	45.3

Table 6. Comparative verification results for the LFM-based surface wind equations for the 18-h projection from 0000 GMT for 39 stations in Alaska for the period March 15, 1981-May 31, 1981 and March 15, 1982-May 31, 1982.

Year	Avg. Fcst. Speed (kt)	Avg. Obs. Speed (kt)	Speed Mean Abs. Error (kt)	No. of Cases	Dir. Mean Abs. Error (degrees)	No. of Cases	Cat. I Bias (Spd. $\leq$12 kt)	No. of Cases	Cat. II Bias (Spd. >12 kt)	No. of Cases	Percent Correct (%)
1981	7.31	7.11	3.91	2581	46.7	1951	0.97	2204	1.18	377	57.7
1982	8.08	7.72	4.28	2507	47.4	1948	0.97	2045	1.12	462	54.2

Table 7. Stations for which surface wind forecasting equations could not be developed for the 0000 GMT cycle. (1=winter, 2=spring, 3=fall, 4=summer; P indicates primary equations, B indicates backup equations)

Station Call letters	12-h (P)	12-h (B)	18-h (P)	18-h (B)	24-h (P)	24-h (B)	30-h (P)	30-h (B)	36-h	42-h	48-h	54-h
ANC												
ANN							234	34				34
BTI												
BET												
BTT												
BIG	34		4		4		4					
CDB												
CDV												
DLG												
FAI												
PAGA	2		2		24		2					
GKN												
HOM												
JNU												
ENA												
AKN												
ADQ												
OTZ												
MCG												
OME												
ORT												
PSG	1234	1234	1234		1234	4	1234	1234	1234		4	1234
BRW												
SNP							3	3				3
SIT												
SGY	1234	1234	1234		1234		1234	1234	1234			1234
TKA												
TAL	1234	1234							234			
VDZ	1234	1234	1234		1234		1234	1234	1234			1234
YAK												
PAED	2		2									
PALU	2		2		2		2					
PAEH	2		2									
PACZ	2		2		2							
PAEI	2		2		2		2					
PAIM	2		24		24		2					
PASV	2		24		24		2					
PATL	24		24		24		24					
PATC	2		24		24		2					

Table 8. Stations for which surface wind forecasting equations could not be developed for the 1200 GMT cycles. (1=winter, 2=spring, 3=fall, 4=summer; P indicates primary equations, B indicates backup equations)

Station Call letters	12-h (P)	12-h (B)	18-h (P)	18-h (B)	24-h (P)	24-h (B)	30-h (P)	30-h (P)	36-h	42-h	48-h	54-h
ANC												
ANN			234	34						34		
BTI												
BET												
BTT												
BIG	1234		1234		1234		1234					
CDB												
CDV												
DLG	1234		1234		1234		1234					
FAI												
FAGA	2				2							
GKN	1		1		12		1					
HOM												
JNU												
ENA												
AKN												
ADQ												
OTZ												
MCG												
OME												
ORT												
PSG	234	4	1234	1234	1234	1234	1234		4	1234	1234	
BRW												
SNP			3	3						3		
SIT												
SGY	34		1234	1234	1234	1234	34			1234	1234	
TKA												
TAL					1234	1234					1234	
VDZ	1234		1234	1234	1234	1234	1234			1234	1234	
YAK												
PAED	2		2		2		2					
PALU	2		2		2		2					
PAEH					2		2					
PACZ	2		2		2		2					
PAEI					2		2					
PAIM	2		2		2		2					
PASV	24		2		2		24					
PATL	24		2		2		24					
PATC	2		2		2		2					

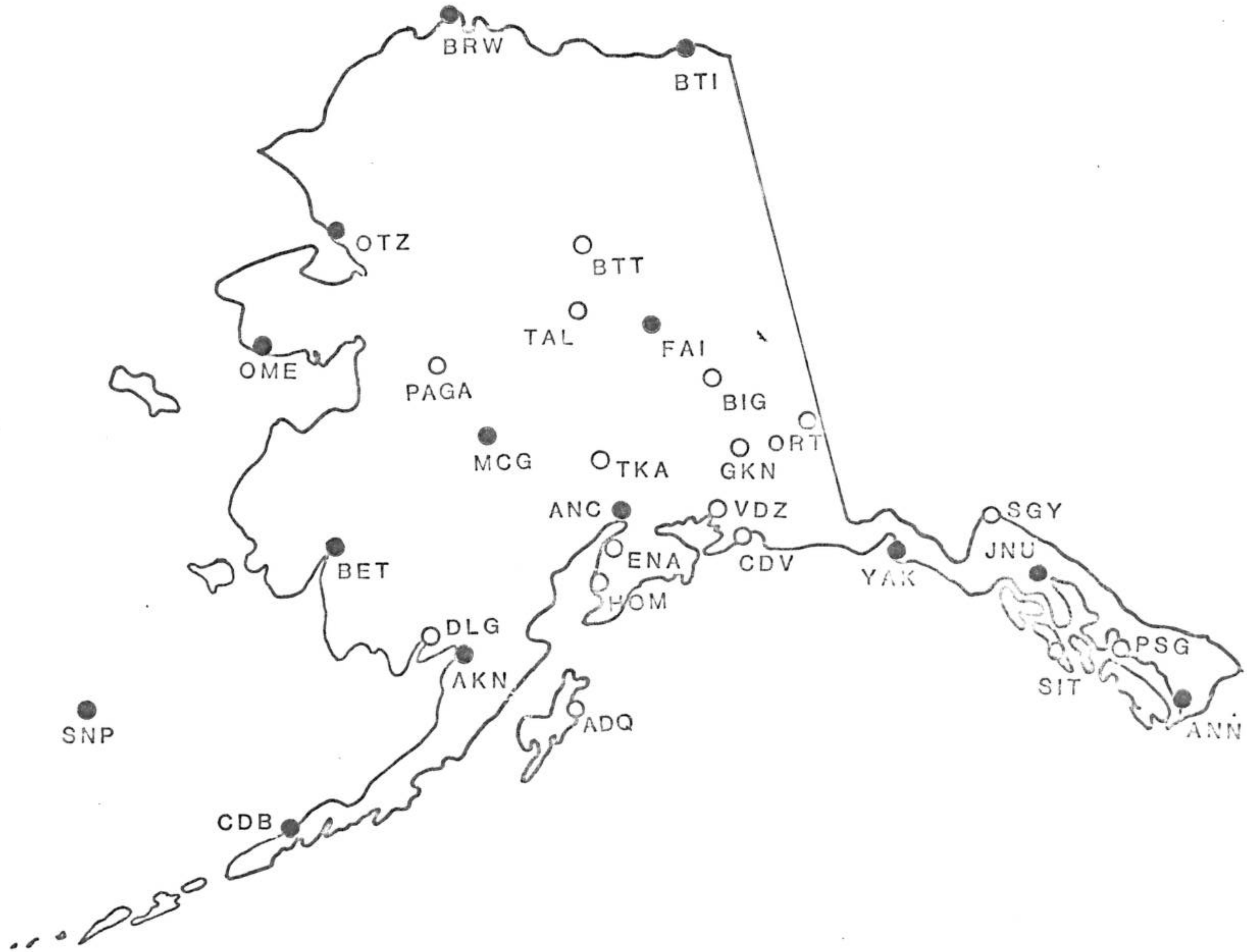

Figure 1. Stations used to develop a new LFM-based surface wind guidance system. Stations designated by closed circles comprised the previously operational, PE-based system.